Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, D.C. 20554

In the Matter of	)	
	)	
Review of the Commission's Ruling	)	
Regarding the Pricing of Unbundled	)	WC Docket No. 03-173
Network Elements and the Resale of	)	
Service by Incumbent Local Exchange	)	
Carriers	)	

DECLARATION OF ROBERT PINDYCK

1. My name is Robert S. Pindyck. I am the Bank of Tokyo-Mitsubishi Professor of Economics and Finance in the Sloan School of Management at the Massachusetts Institute of Technology. Attachment A is a copy of my curriculum vitae.

2. My research has addressed the issues confronting a firm that has the opportunity to invest in a project for which the returns are uncertain. I am the co-author of a book, *Investment Under Uncertainty*, that provides "the first detailed exposition of a new theoretical approach to the capital investment decisions of firms, stressing the irreversibility of most investment decisions, and the ongoing uncertainty of the economic environment in which these decisions are made."[1] The principal finding of my work in this area is that irreversible (i.e., sunk) capital investments usually include an opportunity cost – referred to as option value – associated with the flexibility that must be forfeited when a firm creates a long lived asset. That measure of the cost of the inflexibility of sunk investments was not generally recognized by academic economists prior to the publication of my book.

3. I have been asked by Verizon to examine option value in the context of the FCC's TELRIC pricing rules. I recently wrote a paper addressing this issue, "Mandatory Unbundling and Irreversible Investment in Telecom Networks", which is Attachment B of this declaration. As described in more detail in that paper, when Incumbent Local Exchange Carriers (ILECs) make sunk capital investments in telecommunications network infrastructure they are incurring the opportunity cost of exercising their option to invest. Consequently, when they make these investments they must consider the Telecom Act's mandate to share this capital with competitive entrants. At least as it has been applied to date, TELRIC pricing ignores the option value associated with irreversible capital investments and instead transfers investment value from the ILEC -- which bears the entire downside risk of exposure if its investment does not bear fruit -- to the Competitive Local Exchange Carriers (CLECs). As TELRIC has been applied, the

[1] Avinash K. Dixit and Robert S. Pindyck, *Investment Under Uncertainty*, Princeton University Press, 1994

ILEC *is not compensated for the cost associated with the option value.* Instead of simulating a competitive market (in which investments can expect to receive a competitive rate of return), TELRIC has therefore been applied in a way that undercompensates ILECs for the use of their capital, and thereby discourages investment.

4. Not accounting for option value in the TELRIC price goes beyond a simple transfer of value from ILECs to CLECs; it thwarts the Telecom Act's goals of promoting facilities-based competition. The stated purpose of the TELRIC pricing methodology is to send economically meaningful signals to competitors about the costs of investing in infrastructure.[2] Only with meaningful price signals about the costs that are expected to exist in a competitive environment will the competitor's choice between investing and leasing promote consumer welfare. Omitting an important cost from the calculation of the price a competitor faces sends the wrong signal to entrants.

5. This declaration explains the nature of option value in the telecom network, and also explains that the TELRIC pricing methodology as it has been applied does not include compensation for this option value. The declaration will also describe how option value could be included in an appropriate forward-looking pricing formula. I have begun the initial steps required to calculate a premium that could be added to the cost of capital to account for option value. I plan on submitting the results of that work at a later date.

6. This declaration is organized as follows. Section I explains why investment costs in the local telecommunications network include an option value component. Section II explains why the current TELRIC pricing formula does not incorporate a component for option value. Section III provides an overview of how option value can be included in an appropriate forward-looking pricing formula.

I. OPTION VALUE IN THE TELECOMMUNICATIONS NETWORK

7. The attached paper, "Mandatory Unbundling and Irreversible Investment in Telecom Networks," explains in detail why telecommunications network investments contain option value. Here, I summarize the main points.

8. The decision to make irreversible capital investments in telecommunications network infrastructure constitutes long-term commitments to serve a particular market. At least as it has been applied to date, TELRIC pricing undercompensates ILECs for their investments by ignoring the asymmetric burden of risk that is inherent in unbundling. In reality, future market conditions are (and always will be) highly uncertain. Thus, any investment in network infrastructure yields uncertain returns over the lifetime of the investment.

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[2] FCC, First Report and Order In the Matter of Implementation of the Local Competition Provisions in the Telecommunications Act of 1996, CC Docket No. 96-98 (August 8, 1996), at paragraph 630.

9. When considering a new investment, the network owner sees the opportunity for positive returns in 'good times' as compensation for assuming potential losses should 'bad times' prevail. The obligation to lease access to their network to CLECs changes the ILECs' expected return from an irreversible investment. If market conditions are favorable, the CLEC will go ahead and lease the equipment, but if conditions are unfavorable, it will not do so. In addition, if the CLEC did lease the equipment but conditions later turn unfavorable, the CLEC can end its lease and thereby "uninvest." Taking the 'good times' out of the average lowers the ILEC's expected returns.

10. Thus, unlike the ILEC that actually made the capital investment, the CLEC does not bear the burden of the uncertainty – it benefits on the upside, while avoiding the downside. As it has been applied to date, however, the TELRIC price fails to account for this. As a result, the application of TELRIC pricing has resulted in the ILEC subsidizing the CLEC by bearing the entire cost of downside risk exposure. This uncompensated cost discourages ILEC capital investment by lowering its expected returns from investment. This treatment of risk is equivalent to omitting a costly input when calculating the level of compensation for future investors in network infrastructure.

A. Network Investments

11. If network investments were largely reversible *or* if there was very little uncertainty over the future returns from such investments, then TELRIC's treatment of risk would not be very important, and could probably be ignored. If network investments were largely reversible, an ILEC could simply uninvest if and when market conditions became unfavorable, and would not have to bear the financial consequences of an adverse market. And, of course, if there was very little uncertainty over the future returns from investing, any treatment of risk would be moot to begin with. Note that if *either* of these conditions held, it would be sufficient to allow us to ignore the asymmetry of risk inherent in unbundling. The fact is, however, that neither of these conditions holds: *Network investments are largely irreversible and there is considerable uncertainty over the returns from those investments.*

12. Why are network investments largely irreversible? For some types of investment, recovery through resale is simply not possible. An example is copper or fiber-optic cable that has been placed underground. But what about investments in switches or other equipment that presumably could be uninstalled and resold to some other company? In this case, the problem is that the equipment is *industry-specific*, and its resale value is tightly connected to economic conditions of the industry. Thus, if conditions turned out to be unfavorable because industry wide conditions were weak, so that the firm wished to uninvest by removing and reselling the equipment, it would find that other firms would also want to resell such equipment, and in all likelihood no firm would want to buy the equipment.[3] In other words, *the economic value of the equipment would move up or*

[3] To the extent that the fortunes of a particular company are not associated with the fortunes of the industry, this effect is muted. For example, cars and trucks could probably be resold to companies in other industries (although at prices below the original purchase prices).

down along with the economic conditions of the industry, making the investment effectively irreversible. And in all cases, the installation and removal costs, which can be substantial, are irreversible.

13. Why are the returns from network investments highly uncertain? On the demand side, although the population (and thus the potential market) tends to grow steadily, the willingness to buy various telecom services — particularly those that tend to generate the most revenue — varies considerably with general economic conditions or even current fashions. In addition, there is competition from close substitutes for land-based telephone service, most notably wireless service but also cable and Internet-based service, and the prices and qualities of these substitutes evolve unpredictably. All of this makes demand highly volatile and difficult to predict. On the supply side, the very competition induced by regulation — as well as competition that would arise even without regulation — generates uncertainty over the portion of the customer base that the incumbent will be able to service, and the prices that can be charged.

14. In summary, network investments are largely irreversible and subject to considerable uncertainty. This implies that when a local exchange carrier builds its system, it incurs opportunity costs beyond its actual capital expenditures. The reason is that when the firm makes the investment, it gives up its option to wait to see how uncertainty about markets, costs, and regulations is resolved. Under the FCC's unbundling rules, incumbents are not compensated for this option value, which must be provided to entrants without charge.

B. A Sunk Cost Fallacy

15. The FCC has advanced the idea that wholesale rates should be set on the basis of forward-looking costs, with historical costs disregarded, the intent being to prevent the recovery of costs that were either imprudent or reflective of inefficient old technology. The FCC appears to think that with *new and improved* systems available, competitors should be given access to facilities at their current cost, as if the best systems were deployed. To allow ILECs to recover embedded costs would, as the Supreme Court has put it, promote "some degree of long-run inefficiency."[4] The idea seems to be that just as decision makers in the marketplace disregard sunk costs, so should regulatory price setters.[5]

16. This is incorrect. It ignores the basic fact that sunk costs *do matter* in decision-making when those costs *have yet to be sunk*. The TELRIC pricing rule deters *current* investment by denying investors recovery today of costs previously sunk. The TELRIC pricing rule may do this because equipment costs are falling over time, and/or because there is no compensation for option value – the reason why TELRIC prices deny recovery

[4] Verizon v. FCC, 535 U.S 467 (2002), p. 22

[5] The Supreme Court writes "'Sunk costs' are unrecoverable past costs; practically every other sort of economic 'cost' is forward looking, or can be either historical or forward looking." Ibid., p. 18.

is not important, but the fact that they do is. The lack of compensation for investments already made cannot deter those past decisions, which, by definition, are bygones. But when investors know that new capital outlays will not be recouped, economic behavior changes. Investors rationally commit less new capital in *anticipation* of inadequate returns. Hence, the argument that forward-looking costs are the only relevant considerations confuses the sunk cost fallacy. To achieve an efficient level of irreversible investment requires that capital remuneration is anticipated to include sunk cost payback.

17. In short, a rule depriving investors of the ability to recoup sunk costs becomes part of the forward-looking analysis for capital *not yet sunk*. Of course, if there is no concern about creating incentives for *new* investment, it is reasonable to argue that efficient pricing should be entirely forward-looking and sunk costs should be ignored. But creating incentives for new investment is crucial. Capital depreciates and must be maintained or replaced, and efficient new technologies require new investment. The investment needed to adopt new technologies is especially important in local telecommunications networks. If firms considering investing in more modern systems operate under the rule that TELRIC pricing will not allow them to recover sunk costs, they simply will not sink the capital needed to create the networks of tomorrow.

18. Future sunk investments in the telecom network are important, and should not be ignored. The current value of the local regulated wireline network owned by the Bell Companies is approximately $106 billion.[6] Analysts have noted that the amount of investment needed to sustain the network at its current level is approximately $15 billion to $20 billion per year.[7] It is also worth noting that the network requires a significant amount of investment to serve changing demands even when overall demand is not growing.

C. Overview of Option Value

19. The TELRIC pricing methodology relies on the simple Net Present Value (NPV) investment rule. The NPV rule states that a firm should invest in a project if the sum of the discounted expected cash flows (the NPV) from the project is positive.[8] TELRIC is

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[6] This reflects an estimate of the 2002 book value of the RBOC's local wireline capital stock, calculated by summing the SBC, Bell South, and Verizon net capital stock data reported in the FCC's 2002 ARMIS 43-01 Report and adding 15%. (I add 15% because that was Qwest's average percentage of total RBOC net capital stock for the previous three years I cannot use Qwest's data from ARMIS for 2002 because it is not reported yet)

[7] Skyline Marketing Group reports that the maintenance level for Regional Bell Operating Company investments is 15-20 percent (CapEx/Revenue). Skyline Marketing Group, *CapEx Report: 2002 Annual Report*, June, 2003, p. 18.

[8] That is, if $\mathrm{NPV} = -I_0 - \frac{I_1}{(1+\rho)} - \ldots + \frac{\pi_1}{(1+\rho)} + \frac{\pi_2}{(1+\rho)^2} + \ldots > 0$ where I_0, I_1, . . are investment outlays, π_1, . are net cash inflows arising from the investment, and ρ is the discount rate, often the WACC.

designed to produce prices that provide an ILEC with a competitive return, i.e., with no profits in excess of those that would arise in a competitive market. In other words, under TELRIC the expected NPV of the *included costs* at any given discount rate is zero. The theory behind the FCC's TELRIC methodology is that, if the NPV was greater than zero, additional firms would enter until excess profits were driven to zero.

20. It would be correct for TELRIC to rely on the NPV rule if telecommunications investment was completely reversible. It would also be correct if there was no uncertainty over the future cash flows, or if this investment was a now-or-never proposition (i.e., there is no possibility of delaying the investment). However, in the present case, investment is in fact largely irreversible, there is uncertainty over the cash flows, and the investment could be delayed. In these circumstances, the use of the simple NPV rule is incorrect because it does not maximize the firm's value, i.e., the firm would do better making investments under different assumptions than those used in the NPV rule.

21. Why is this NPV rule an incorrect way for a company to determine whether to invest, and accordingly not the rule the FCC should use to compute prices? Because it makes the wrong comparison – it compares investing today with never investing. The correct comparison is investing today versus waiting, and perhaps (depending on how market conditions turn out) investing at some unspecified time in the future. Put differently, a firm with an opportunity to invest holds an *option* analogous to a financial call option – it has the right but not the obligation to buy an asset at some future time of its choosing. When a firm makes an irreversible investment expenditure, it exercises its option to invest. It foregoes the possibility of waiting for new information to arrive that might affect the desirability or timing of the expenditure; it cannot disinvest should market conditions change adversely.

22. Making an investment and giving up the value of waiting, therefore, entails a cost. This lost option value is an opportunity cost that must be included as part of the total cost of the investment. If the option value is not recognized as a cost of the investment, the calculation of a break-even point will be in error. As a result, the NPV rule -*Invest when the value of a unit of capital is at least as large as its purchase and installation cost*- must be modified. The value of the unit must exceed the purchase and installation cost by an amount equal to the value of keeping the investment option alive.

II. TELRIC DOES NOT INCLUDE OPTION VALUE

23. TELRIC pricing formulas do not explicitly include a cost category for option value. Might the way TELRIC is implemented account for option value is some other component of the formula? It appears not. The most likely candidates would be the cost of capital or the depreciation schedule. As far as I have been able to determine, the TELRIC pricing formula has not included an adjustment to the cost of capital or depreciation schedules to account for option value.

24. As explained below, option value is not included in the conventional cost of capital measure, the Weighted Average Cost of Capital ("WACC"), which is an important part of the TELRIC formula. Likewise, it is not included in the depreciation measures used in TELRIC. As I also discuss below, this is evident in one notable example of TELRIC pricing, the Wireline Competition Bureau's implementation of TELRIC pricing in Virginia (Virginia Order). That Order does not make an adjustment for option value in either the cost of capital calculations or in the depreciation schedules used.

A. Option Value is not Incorporated in the Cost of Capital

25. Some have claimed that option value is already accounted for in the cost of capital.[9] They argue that an input to the calculation of the TELRIC price is the cost of capital, which includes a premium to cover the option value inherent in an irreversible investment. This is not true. The cost of capital used in most TELRIC price formulations is the ILEC's, or a hypothetical firm's, weighted average cost of capital, which is simply an average of its expected return on equity and its cost of debt, with the weights being the relative shares of equity and debt.

26. This WACC does not incorporate any adjustment for option value. Nor is it intended to. To understand why, note that the WACC is simply the firm's opportunity cost of capital, i.e., it is the expected return on a *reversible* investment with risk characteristics similar to those for the firm as a whole. The WACC is used to discount future cash flows from a reversible investment because the next best use of the firm's capital (opportunity cost) is to repurchase the firm's debt or equity (the components of the WACC), which could be resold (or uninvested) at a later date. However, the WACC is *not* the threshold expected return (or hurdle rate) needed to justify an irreversible investment. It would be the threshold expected return (or hurdle rate) if the investment in question was reversible, or if the firm had no option to delay investing and thereby wait for more information about market conditions. If, on the other hand, the investment in question is irreversible (as is usually the case in the telecom industry), *the hurdle rate must exceed this opportunity cost of capital.*

27. Many people (including economists) are confused by this point. Another way to think about it is to remember that the firm can benefit by waiting for information, and thereby avoiding a bad state of the world where an investment yields a negative return. If the firm behaves optimally, it takes this opportunity cost into account. In a competitive market, all firms take this into account and on average earn a competitive return on capital – namely the competitive WACC. There is no reward for investing sub-optimally,

[9] For example, the FCC claims that all risks are included in the cost of capital. See, Federal Communications Commission, Report and Order and Order on Remand and Further Notice of Proposed Rulemaking, In the Matter of Review of the Section 251 Unbundling Obligations of Incumbent Local Exchange Carriers, CC Docket No. 01-338, Implementation of the Local Competition Provisions of the Telecommunications Act of 1996, CC Docket No. 96-98, Deployment of Wireline Services Offering Advanced Telecommunications Capability, CC Docket No. 98-147, paragraphs 677-684.

e.g., for ignoring this opportunity cost when determining the hurdle rate for a project. The WACC prevails on average, but for any specific irreversible investment, the opportunity cost is the WACC *plus the cost of exercising the firm's option to invest.* Thus the WACC alone does *not* account for option value.

B. The Virginia Order

28. The FCC Wireline Competition Bureau clearly indicates that, in principle, option value should be included as part of the cost of capital. The Virginia Order summarizes Verizon's claim that the cost of capital should reflect the "increased risk of stranded investment."[10] But this is precisely the component of cost that accounts for the asymmetric treatment of risk embodied in unbundling – a CLEC will lease a UNE only if market conditions turn out to be favorable, while the ILEC bears all of the downside risk. The "increased risk of stranded investment" imposes an opportunity cost on the ILEC when it invests, and Verizon has claimed (and I would agree) that this opportunity cost should be part of the overall opportunity cost that we call the cost of capital.

29. The Virginia Order does not provide any means for an ILEC to recover the option value associated with UNEs through TELRIC. In that Order, the Bureau staff base all adjustments for all risks on the WACC. They agree that the WACC does not include an adjustment for option value.[11]

30. What about the calculation of depreciation, which also receives considerable attention in the order? Might the option value be included somehow in the depreciation numbers? Based on my reading of the order, the answer is clearly no.

31. As the Virginia Order reminds us, the FCC's rules simply require the use of "economic depreciation," and that "existing regulatory depreciation rates ... could be 'adjusted upward if the incumbents demonstrate the need.'"[12] But again the order only discusses two aspects of depreciation – the useful life of the asset, and the rate at which it is depreciated over that useful life. Interestingly, the useful life of an asset and the rate at which it depreciates (in economic terms) affects the size of the option value – if the life of the asset was only one year, there would be little or no option value, because there would be little in the way of a sunk cost. Thus the rate of economic depreciation can inform us about the size of the option value. However, option value itself is not recovered (or captured) in the TELRIC formula through depreciation.

32. As I read it, there is nothing in the FCC Wireline Competition Bureau's discussion of depreciation that in any way suggests that the depreciation schedule can be or should be adjusted in order to capture all or part of the option value. Although the

[10] FCC, Memorandum Opinion and Order, DA 03-2738 (August 29, 2003), at paragraph 61.

[11] FCC, Memorandum Opinion and Order, DA 03-2738 (August 29, 2003), at paragraph 61 footnote 195.

[12] FCC, Memorandum Opinion and Order, DA 03-2738 (August 29, 2003), at paragraph 105.

discussion of depreciation schedules is lengthy, it in no way reflects an attempt to include option value in the TELRIC price.

III. FORWARD-LOOKING PRICING WITH OPTION VALUE

33. The existence of real options in the telecommunications network and their exclusion from current TELRIC pricing would only be of academic interest if it were not possible to price the option value in the context of an appropriate forward-looking pricing methodology. Fortunately, option value can be included in such a pricing formula. Although there are many ways to include this additional cost of investments, a straightforward methodology can be developed that simply adds a premium to the cost of capital used in calculating the capital component of individual UNE prices. Here I describe an approach to calculate that premium. I am in the process of implementing this approach and will submit the results of that effort at a later date.

34. For purposes of analyzing option value, the salient feature of the ILEC-CLEC relationship is that, to obtain capital, the ILEC must make an irreversible investment, but the CLEC can rent access to the ILEC's capital at its own discretion. Under these circumstances, the choices that the CLEC faces are equivalent to the choices it would face if investments in the telecom network were completely reversible, i.e., did not involve any sunk costs, and the CLEC and ILEC were on equal footing with respect to scale and scope economies. In essence, to properly account for option value we want to attach a price to this ability of the CLEC to access capital reversibly.

35. To measure the value of the ability of the CLEC to access capital reversibly, I compare it to a hypothetical state of the world where the CLEC, like the ILEC, can only access capital by making irreversible investments. Because the aim of the UNE program and the TELRIC methodology is to price network elements at a competitive level, assuming away any competitive advantage the ILEC may have in economies of scale and scope, the natural hypothetical is one where the CLEC invests in network infrastructure, with the irreversibility that such investment entails, but where the CLEC enjoys the same economies of scale and scope as the ILEC. This represents the world as the Telecom Act envisions it: non-incumbent telecommunications firms compete with their own facilities against incumbent firms and each other.

36. The basic approach can be summarized as follows. I begin with a simple model of the demand for telecom services. The model starts by recognizing that some customers are undesirable to a CLEC, but will be served by an ILEC, while other customers will be attractive to both providers. Consequently, the contest between the ILEC and CLEC is in the sub-market for the more valuable customers. The choice variable for the ILEC is the level of irreversible capital investment to undertake. It must first serve all of its low valued customers and then it can deploy additional irreversible capital to serve high valued customers. In choosing the level of capital investments to make, the ILEC takes into account the fact that the CLEC will be able to rent that capital on a short term basis. In this analysis I abstract from changing technology or other

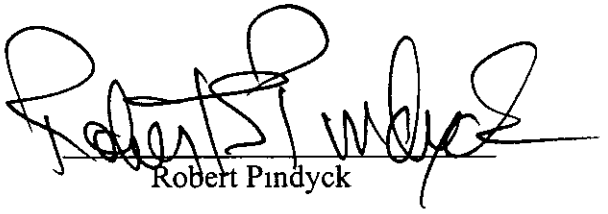
problems associated with TELRIC and its current implementation and assume for the sake of argument that it is an adequate compensation for the actual capital expenses incurred by the ILEC. In this way, our final measure of option value will only capture the effects of the option we are trying to measure and not inadvertently correct for other deficiencies of the TELRIC formulation.

37. Next, I hypothesize that the CLEC, like the ILEC, must invest irreversibly. Everything else – demand, variable costs, and the cost of capital – remains the same. In determining the CLEC cost of investment, consistent with the Telecom Act's guidance, I assume that there are no scale or scope economies that the CLEC must overcome. Put another way, I model the CLEC costs such that they enjoy the same scale and scope economies in their network as the ILEC. In this hypothetical case, the CLEC faces an additional cost that it did not face before, namely, the opportunity cost of irreversibly exercising an option to invest. (This additional cost, of course, is always borne by the ILEC.) The CLEC is a facilities based competitor, and consistent with the intent of the Telecom Act, I assume that it faces no barriers to entry. The amount of investment that the CLEC will make in this hypothetical facilities based setting will be smaller than the amount of investment it leases from the ILEC in the baseline model.

38. Finally, I return to the first model in which the CLEC can lease the ILEC's capital at will. In that model, the quantity of capital the CLEC leases is negatively related to the cost of capital. I adjust the first model by increasing the cost of capital in the TELRIC rate to the point where the quantity of capital the CLEC leases becomes just equal to the quantity it buys in the hypothetical where it, like the ILEC, must invest irreversibly. This exercise replicates the market shares of the ILEC and the CLEC in the world of TELRIC priced UNEs that would prevail in the hypothetical world of CLEC access to capital investments with the same scale and scope economies that the ILECs enjoy. That calculated increase in the cost of capital is the premium that must be added to the TELRIC rate to account for option value.

39. This concludes my declaration.

I declare, under penalty of perjury, that the foregoing is true and correct.



Robert Pindyck

Executed on: December 12, 2003

ATTACHMENT A

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S.M., Electrical Engineering, M.I.T., 1967
Ph.D., Economics, M.I.T., 1971

Academic and Research Appointments:

1971-1975	Assistant Professor, Sloan School of Management, M.I.T.
1975-1979	Associate Professor, Sloan School of Management, M.I.T.
1979-1988	Professor, Sloan School of Management, M.I.T.
1988-2000	Mitsubishi Bank Professor, Sloan School of Management, M.I.T.
2000-	Bank of Tokyo-Mitsubishi Professor, Sloan School of Management, M.I.T.
1983-	Research Associate, National Bureau of Economic Research
1985-1986	Visiting Professor of Economics and Fellow, Institute of Advanced Studies, Tel-Aviv University
2000-2001	Visiting Professor, Harvard University, Graduate School of Business

Professional Organizations:

American Economic Association
American Finance Association
Econometric Society (Fellow)
International Association for Energy Economics
Association of Environmental and Resource Economists (President, 1984)

Honors and Awards:

Mortimer and Raymond Sackler Fellow, Tel-Aviv University (1985, 1987)
Outstanding Teaching Award, Graduate Student Council, M.I.T. (1989)
Elected Fellow of the Econometric Society (1993)
Graduate Teaching Award, Graduate Student Council, M.I.T. (1994)
Alumni/ae Award for Innovation and Excellence in Management Education (1994)
Outstanding Teaching Award, M.I.T. Sloan School (1995)
Outstanding Contributions to the Profession Award, International Association for Energy Economics (1997)
Excellence in Teaching Award, M.I.T. Sloan School (2002)
"All Star Paper Award", *Journal of Financial Economics*, for "Time to Build, Option Value, and Investment Decisions" (2002)

Editorial Boards:

Advisory Editor, *Journal of Economic Dynamics and Control* (1978-1987, 1995-)
Associate Editor, *Energy Economics* (1978-)
Advisory Editor, *The Journal of Energy and Development* (1978-)
Editorial Board Member, *Energy Systems and Policy* (1980-)
Associate Editor, *Journal of Industrial Economics* (1995-1998)
Co-Editor, *Review of Economics and Statistics* (1996-2002)

Consulting - Public Organizations (Partial List):

Institute for Applied Economic Research, Montreal (1971-1981)
Ministry of Planning, Government of Tunisia (1971-1973)
Federal Reserve Board of Governors, Division of Research and Statistics (1972-1974)
Federal Energy Administration (1975-1976)
Member, Energy Facilities Siting Council, Commonwealth of Massachusetts (1975-1977)
The World Bank (1976-1981, 1988-1991)
Ministry of Foreign Affairs, Government of Japan (1979-1980)
Tennessee Valley Authority, Office of the General Counsel (1980-1984)
Federal Trade Commission (1981)
Special Consultant, U.S. Department of State (1987-1990)
Petroleos de Venezuela (1992)
U.S. Department of Energy (1993)
U.S. Department of Justice, Antitrust Division (1997-1999)
Ministry of Energy and Mines, Government of Ecuador (2000-2001)
Federal Energy Regulatory Commission (2002-)

Consulting - Private Organizations (Partial List):

Director, Dynamics Associates, Inc. (1969-1977)
New England Electric System (1977-1978, 1987-1988, 1993-1995)
American Telephone & Telegraph Co. (1978-1979)
International Business Machines (1983-1984)
Uniroyal Corporation (1984)
Panhandle Eastern Pipe Line Co. (1985)
National Economic Research Associates (1986-1988)
Westinghouse Electric Corp. (1987)
Analysis Group, Inc. (1988-)
The Mitsubishi Bank, Tokyo (1989)
Nippon Steel Company (1990-1991)
Microsoft Corporation (1992)
Siemens Corporation (1992)
Lotus Development Corporation (1993-1995)
Compaq Computer Company (1995-1996, 1999-)
British Airways (1994-1999)
Biogen, Inc. (1997-2000)
Cadence Design Systems (1998-1999)
Hasbro, Inc. (1998-1999)
MasterCard International (1998-)

PUBLICATIONS

Books:

Optimal Planning for Economic Stabilization, North-Holland Publishing Company, Amsterdam, 1973.

The Economics of the Natural Gas Shortage. 1960-1980 (with P.W. MacAvoy), North-Holland Publishing Company, Amsterdam, 1975.

Price Controls and the Natural Gas Shortage (with P.W MacAvoy), American Enterprise Institute, Washington, DC, 1975.

Econometric Models and Economic Forecasts (with D.L. Rubinfeld), McGraw-Hill Book Company, New York, 1976; Second Edition, 1981; Third Edition, 1991; Fourth Edition, 1998.

Editor: *Advances in the Economics of Energy and Resources*, Vol 1: *The Structure of Energy Markets*, Vol 2: *The Production and Pricing of Energy Resources*, JAI Press, Greenwich, CT, 1979.

The Structure of World Energy Demand, M.I.T. Press, Cambridge, MA, 1979.

Microeconomics (with D.L. Rubinfeld), Prentice Hall Publishing Company, Upper Saddle River, NJ, 1989; Second Edition, 1992; Third Edition, 1995, Fourth Edition, 1998, Fifth Edition, 2001

Investment Under Uncertainty (with A.K. Dixit), Princeton University Press, Princeton, NJ, 1994.

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